

UNSTABLE APPROACHES: A Global Problem

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David Ross joined the TSB staff as an air operations investigator in 1999. He previously worked as a weather observer; as a transport pilot, training pilot, check pilot, and flight operations supervisor with the Canadian Forces; and as a regional airline pilot in western Canada.

Mr. Ross worked as the operations team leader, and chair of the flight operations and weather groups, during the TSB investigation of a Boeing 737 controlled flight into terrain accident at Resolute Bay, Nunavut, on 20 August 2011. (1)

Independence and Collaboration

The Transportation Safety Board of Canada, or TSB, is an independent agency dedicated to advancing transportation safety. The TSB conducts independent investigations of selected transportation occurrences to determine causes and contributing factors, and then reports publicly on what has been learned.

To instill confidence in the public regarding the investigation process, it is essential that an investigating agency be independent and free from any conflicts of interest when conducting an investigation. As such, the TSB is an independent agency, separate from other Canadian government agencies and departments. TSB final reports and safety communications are not subject to government revision or approval. Our independence enables us to be fully objective in making findings as to causes and contributing factors, and in making transportation safety recommendations.

However, while the TSB is independent of other organizations, we recognize that collaboration is essential to the effective conduct of an investigation. This collaborative approach is enabled through ICAO Annex 13, as well as the TSB legislation, regulations, investigation policies and procedures.

So, how do we conduct an independent investigation when we are collaborating with others? The collaboration is initially focused on data collection under the direction and control of the TSB. The TSB then conducts its analysis of the data independently of any other organization. This independent analysis, in the form of a confidential draft report, is then provided to designated reviewers who are asked to review and make representations on the report. In this second collaborative phase, the TSB considers the representations only for their contribution to the accuracy and soundness of the report and for their contribution to the advancement of transportation safety. The findings in the final report released to the public are those of the TSB.

The Accident

On 20 August 2011, a Boeing 737-210C was operating as First Air flight 6560 from Yellowknife, Northwest Territories, to Resolute Bay, Nunavut (Figure 1). During the instrument landing system approach to Runway 35 True at Resolute Bay, the aircraft progressively diverged to the right of course. The crew initiated a go-around after a ground proximity warning system “sink rate” alert occurred, but there was insufficient altitude and time to execute the manoeuvre and avoid collision with terrain. The aircraft struck a hill about 1 nautical mile east of the runway and was destroyed by impact forces and a post-crash fire (Figure 2). Eight passengers and all 4 crew members died in the crash, and the 3 surviving passengers were seriously injured. The accident occurred during daylight in instrument meteorological conditions.

TSB Response

In August 2011, the TSB was conducting an exercise field investigation to test equipment and procedures. The scenario was a simulated mid-air collision at Resolute Bay with a large scale multi-department government response to a major air disaster. The TSB exercise team was on a Royal Canadian Air Force (RCAF) C-17 that landed at Resolute Bay about one hour after the accident. The TSB team immediately shifted from exercise to investigation mode and began collecting information. The TSB deployed additional investigators to Resolute Bay and Yellowknife. The cockpit voice recorder (CVR) and flight data recorder (FDR) were recovered and transported to the TSB Laboratory in Ottawa, where another team was formed.

ICAO Annex 13 notification provided an accredited representative from the National Transportation Safety Board with technical advisors from Boeing, Pratt & Whitney, and the FAA. Other organizations participating in the investigation were First Air, Transport Canada, ALPA, and the RCAF.

As mentioned previously, the initial portion of the investigation focused on data collection both at the crash site and elsewhere. All of the organizations mentioned above participated in this collaborative phase, with TSB investigators leading functional groups.

Sequence of Events

An important part of the TSB investigation process is the development of a sequence of events, and the identification and analysis of safety significant events. Information for the sequence of events of this accident came primarily from the flight data recorder, the cockpit voice recorder, and a military air traffic control radar system that was operating at Resolute Bay. The sequence of events was depicted in several ways as follows: a plan view of the flight path (Figure 3), an event sequence in the TSB safety analysis software module (Figure 4), a word processor table (Figure 5), FDR data plots (Figure 6), and an engineering flight animation (Figure 7). While the sequence of events was developed in collaboration with other organizations, analysis of the events was done independently by TSB investigators.

Many events during the arrival of First Air flight 6560 warranted further investigation and are described in the investigation report; however, this presentation will focus on only selected events as they relate to crew resource management and the continuation of an unstable

approach. There were also many events that were not recorded that warranted further investigation, especially autopilot and flight director mode changes that should have occurred during the approach.

Autopilot and Flight Director Mode Changes

The FDR showed that the autopilot was engaged throughout the arrival of flight 6560. The captain would have needed to make both autopilot and flight director mode selections (Figure 8) as the flight approached from the southwest toward the localizer. However, only the autopilot engagement status was included in the limited number of parameters on the FDR. Additionally, the operator's standard operating procedures at the time did not require crew callouts of mode selections or changes, and none were recorded on the CVR. The challenge to the investigation was to understand and explain how the pilots likely operated these systems and what information they had available during the approach.

During the on-site work at Resolute Bay, the NTSB accredited representative suggested that the use of a flight simulator could be beneficial to the investigation. The TSB accepted this idea, and a simulator project team headed by the author was formed.

In addition to TSB investigators, the simulator team included representatives from the NTSB, Boeing, FAA, and First Air. The team had broad expertise, and included investigators, engineers, pilots, and human performance experts. Following several months of extensive planning, the team convened in Vancouver in March 2012, and conducted about ten hours of simulator work over two days (Figure 9, Figure 10). A key factor in the successful completion of this project was the collaboration of multiple organizations, each with its own expertise.

The simulator project produced two key pieces of information. First, that a pilot applying sufficient force on the control wheel could cause the autopilot to shift modes without inducing any roll. Second, that use of the VOR/LOC mode resulted in either interception of or convergence with the localizer in every case. Both of these ultimately played a role in the analysis and findings.

Follow-on meetings of the simulator team led to examination of decades-old engineering documents to establish the conditions and limitations for autopilot and flight director localizer capture.

During the analysis phase, TSB investigators examined dozens of segments of the flight to make conclusions as to the likely autopilot and flight director system states and mode changes.

This portion of the investigation produced two findings as to causes and contributing factors. First, that, as the aircraft rolled out of the turn onto final approach, the captain likely made a control wheel roll input that caused the autopilot to change to a mode wherein the aircraft rolled to and maintained wings level, and that the crew did not detect the mode change. Second, that the flight directors likely subsequently changed modes, resulting in a change of pilot roll guidance.

Crew Resource Management

Crew resource management, or CRM, was identified as a potential safety issue within the first week of the investigation when the initial CVR transcript became available. The CVR recording was essential to the analysis of the role CRM played in this accident and the TSB final investigation report made extensive use of those extracts of the CVR recording related to causes and contributing factors or the identification of safety deficiencies.

Data collection for this portion of the investigation involved gathering and reviewing hundreds of documents, conducting interviews with the peers of the occurrence pilots, observing the operator's CRM training delivery, and careful examination of the operator's flight operations policies and procedures.

TSB investigators repeatedly reviewed and analyzed the CVR recordings. As important as what was said was how it was said, and the current operational cockpit context in which it was said. As with the autopilot and flight director analysis, investigators examined dozens of segments of the flight to understand why the pilots did and said what they did.

The analysis of CRM on flight 6560 focused on several of the mandatory CRM training topics required by the Canadian Commercial Air Services Standards. Two of these were workload management and communications.

Ineffective workload management resulted in the flight 6560 pilots becoming task-saturated and shedding tasks during the final two minutes of the flight. A prime example of this was an 80 second discussion on final approach about the flight's divergence from the localizer (Figure 11). During this period the crew became immersed in the navigational issue and did not action the remaining landing checklist items to finish configuring the aircraft for the approach. Once final configuration changes did occur, they were hurried and neither pilot made all of the specified callouts.

Analysis of the sequence of events identified many instances of ineffective communication between the pilots. Communications difficulties were exacerbated by standard operating procedures that did not specify standard phraseology to operationalize company operating policies for stable approaches. One example of this was the first officer's statement that they were at 3 miles and not configured. The investigation concluded that it is almost certain that the intended message was that the approach was unstable and a go-around was required. However, the captain's interpretation of this statement was that they needed to finish configuring the aircraft for landing.

This critical miscommunication occurred while each crew member likely had a different mental model of the current situation and the aircraft flight path. The investigation concluded that the captain's mental model was likely that the autopilot would re-intercept the localizer from the right and a landing would follow. However, the first officer's mental model was likely that flight 6560 was full deflection from the localizer, was still diverging to the right of course on an unstable approach, and a go-around was necessary. The final report included a finding as to causes and contributing factors that the crew did not maintain a shared situational awareness

and that, as the approach continued, the pilots did not effectively communicate their respective perception, understanding, and future projection of the aircraft state.

This portion of the investigation led to several findings as to causes and contributing factors. Key among them was an overarching finding that the crew's CRM was ineffective, and another finding that adaptations to standard operating procedures by the crew contributed to their ineffective CRM.

The investigation also examined one of First Air's Boeing 737 bases to determine whether any of the standard operating procedure adaptations identified in flight 6560 existed elsewhere in the company. The final report included a finding as to causes and contributing factors that other 737 pilots did employ adaptations, and that the operator's supervisory activities did not detect the adaptations.

Investigators also studied the company's CRM training program. The initial CRM course used presentations prepared by Transport Canada in the mid-1990s, and 5 of the required subjects were not presented during the one-day course observed by TSB investigators. The recurrent CRM course was more up-to-date, including elements of more recent generations of CRM training, but consisted of only two hours training. The investigation made a finding as to causes and contributing factors that the company's initial and recurrent CRM training did not provide the crew of flight 6560 with sufficient practical strategies to enable effective CRM.

The Canadian CRM training standard was also scrutinized. This standard was brought into force in 1996 in response to TSB recommendation A95-11 which called for CRM and decision-making training to be mandatory for all operators and aircrew involved in commercial aviation. However, the standard has remained unchanged in the intervening years, while CRM best practices and training methods have evolved through several updated generations. The TSB final report for the Resolute Bay investigation included a finding as to risk that current Transport Canada crew resource management training standards and guidance material have not been updated to reflect advances in crew resource management training, and there is no requirement for accreditation of crew resource management facilitators/instructors in Canada. This situation increases the risk that flight crews will not receive effective crew resource management training.

The TSB issued a recommendation (A09-02) in 2009 that Transport Canada require commercial air operators to provide contemporary crew resource management (CRM) training for air taxi and commuter pilots. Transport Canada accepted the recommendation. Over the past 5 years Transport Canada has worked toward updating the CRM training standard and expanding CRM training into all sectors of commercial flight operations.

The TSB reassesses all recommendations annually to determine what progress has occurred. During the 2014 reassessment, the TSB rated Transport Canada's progress on this recommendation as SATISFACTORY INTENT, but expressed concern about the slow pace of action to address this recommendation, especially when no information was provided about when the new standard was expected to come into force.

When the Resolute Bay investigation report was released, the TSB issued another Board concern that, without a comprehensive and integrated approach to CRM by TC and aviation operators, flight crews may not routinely practice effective CRM.

Unstable Approaches

As was the case with CRM, within the first week after the accident the investigation had identified an unstable approach as a potential safety issue. The company had in place both a no-fault go-around policy and a stable approach policy with detailed criteria that became applicable during an approach in IMC at 1000 feet above aerodrome elevation. Initial plots of the flight 6560 FDR data showed that the indicated airspeed recorded at this point in the approach was 176 knots, 44 knots greater than V_{ref} . This was well in excess of the company specified limit of $V_{ref} + 20$ knots. Once the FDR data was integrated with the CVR and radar flight path, four additional unstable parameters were identified.

Two key questions the investigation looked into are as follows. First, why was an unstable approach continued despite policies in place to prevent this? Second, did continuing an unstable approach introduce unacceptable risk?

The investigation revealed that the company's stable approach policy had not yet been translated into procedural guidance in the aircraft operating manuals for the company's various fleets. Consequently, when flight 6560 entered the stable approach zone, the first officer needed to improvise because he did not have any standard phraseology to communicate clearly to the captain that the approach was unstable and they needed to go-around. As discussed above, the first officer's attempt to communicate this was misunderstood by the captain, who commenced the final landing configuration changes rather than initiating a go-around.

Part of the TSB risk analysis process is to identify similar occurrences. Investigators reviewed investigation reports from Canada and other countries and identified many occurrences that had an unstable approach as a contributing factor. These occurrences demonstrate that the severity can range from no injuries or damage to multiple fatalities and aircraft destruction. They also demonstrate that, despite a significant industry effort to put in place defences to mitigate the risks associated with unstable approaches and their consequences, the current defences are not always robust enough to prevent catastrophic outcomes.

LOSA and flight data monitoring programs are two means for airlines to identify risks present in their operations, including unstable approaches. However, LOSA is voluntary and First Air has not participated in the program. At the time of the accident, First Air was putting in place a flight data monitoring program, but had not yet achieved results because of data collection and quality problems.

LOSA observations of over 20,000 flights show that 4% of those flights had an unstable approach (Figure 12), and that 97% of the unstable approaches continued to a landing (Figure 13). On only 3% of unstable approaches did the crews execute a go-around. (2)

In 2013, a worldwide fleet of western-built jet aircraft weighing greater than 60,000 pounds made 25.2 million departures. (3) Assuming the LOSA unstable approach information is

representative of this fleet, that means that in 2013 almost 1 million of those flights ended with an unstable approach to a landing. To put that in perspective, since I began this presentation, about 35 flights have landed somewhere in the world from an unstable approach. That does not include smaller jet aircraft and a large fleet of turboprop aircraft also used by airlines.

In its final report on this investigation, the TSB urged the Canadian aviation industry to take three steps to reduce this risk to the system.

- First, for operators to have practical and explicit policies, criteria, and SOPs for stabilized approaches that are enshrined in the company operating culture.
- Second, for companies to have contemporary initial and recurrent CRM training programs delivered by qualified trainers, and to monitor and reinforce effective CRM skills in day-to-day flight operations.
- Third, to monitor SOP compliance through programs such as flight data monitoring (FDM) and line-oriented safety audits (LOSA).

In Canada, Transport Canada requires airline operators to have SMS, CVRs, and FDRs. However, these air carriers are not required to have an FDM program. Even so, many of these operators routinely download their flight data to conduct FDM of normal operations. Air carriers with flight data monitoring programs have used flight data to identify and mitigate many problems, including unstable approaches.

In its final report, the TSB concluded that, unless further action is taken to reduce the incidence of unstable approaches that continue to a landing, the risk of approach and landing accidents will persist. Therefore, the TSB issued Recommendation A14-01 that: Transport Canada require Canadian airline operators to monitor and reduce the incidence of unstable approaches that continue to a landing.

Transport Canada agreed with the intent of the recommendation, and, on 27 June 2014, issued a Civil Aviation Safety Alert requesting Canadian airline operators to use their existing SMS processes to address and mitigate hazards and risks associated with unstable approaches. This safety alert also indicated that, beginning in 2015-2016, Transport Canada will, within the context of normal surveillance activities, assess the effectiveness of the various measures undertaken by airlines in reducing the number of unstable approaches that continue to a landing, including how airlines track, analyze and implement corrective measures.

Conclusion

In conclusion, the TSB can emphatically state that “Independence does not mean isolation.” Teamwork is essential in every investigation, and investigators should be encouraged to surround themselves with experts and to collaborate with them.



Figure 1: First Air Flight 6560 Route Map

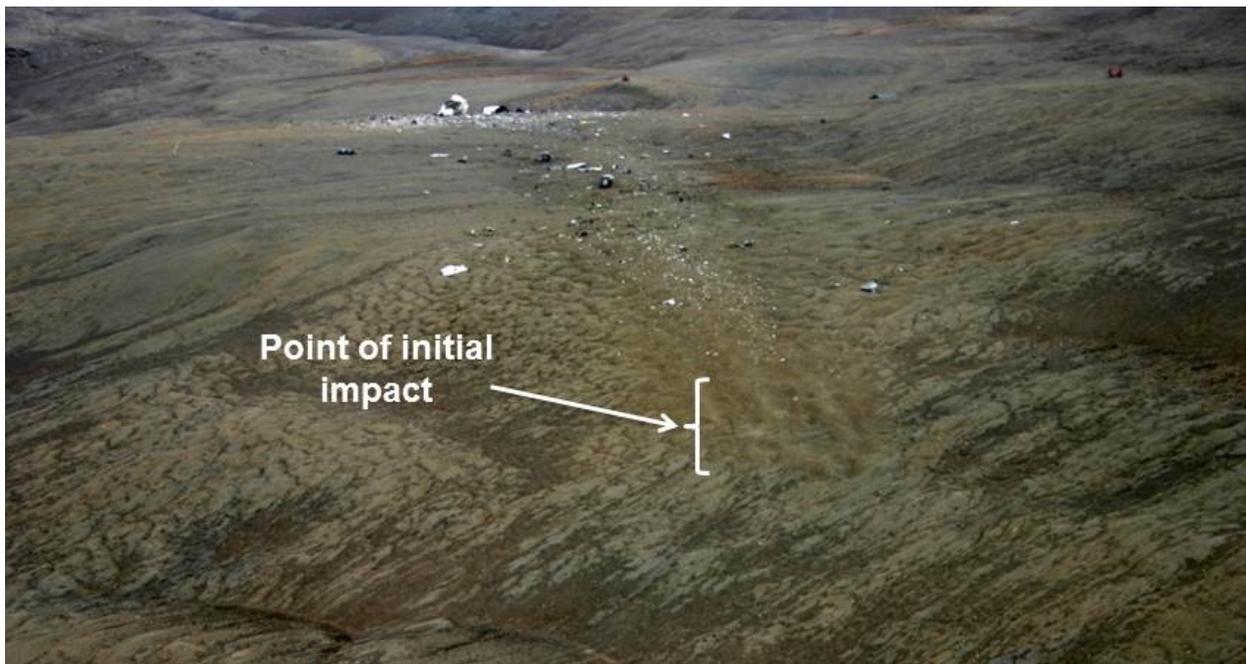


Figure 2: Accident Site Looking North

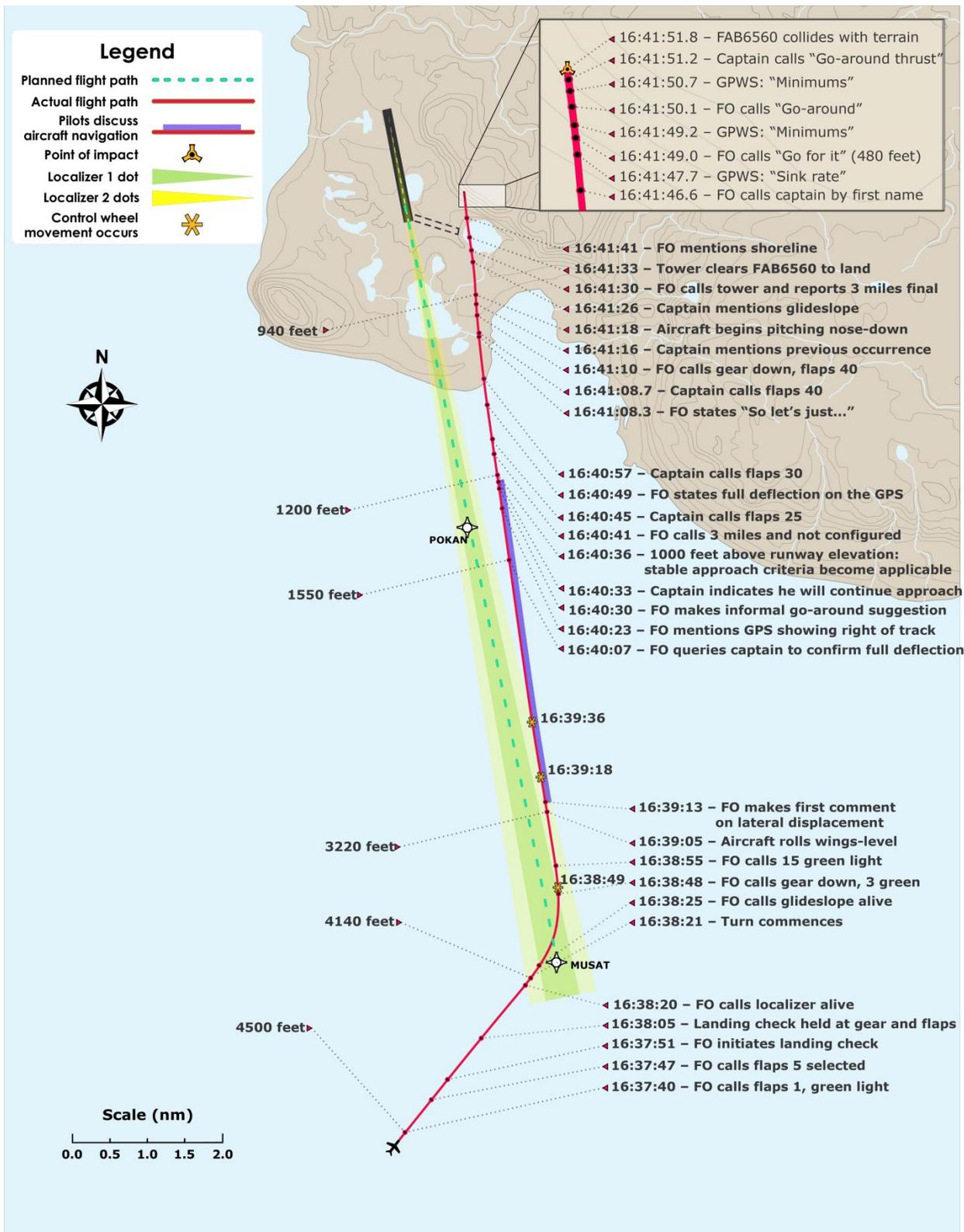


Figure 3: Sequence of Events, Plan View

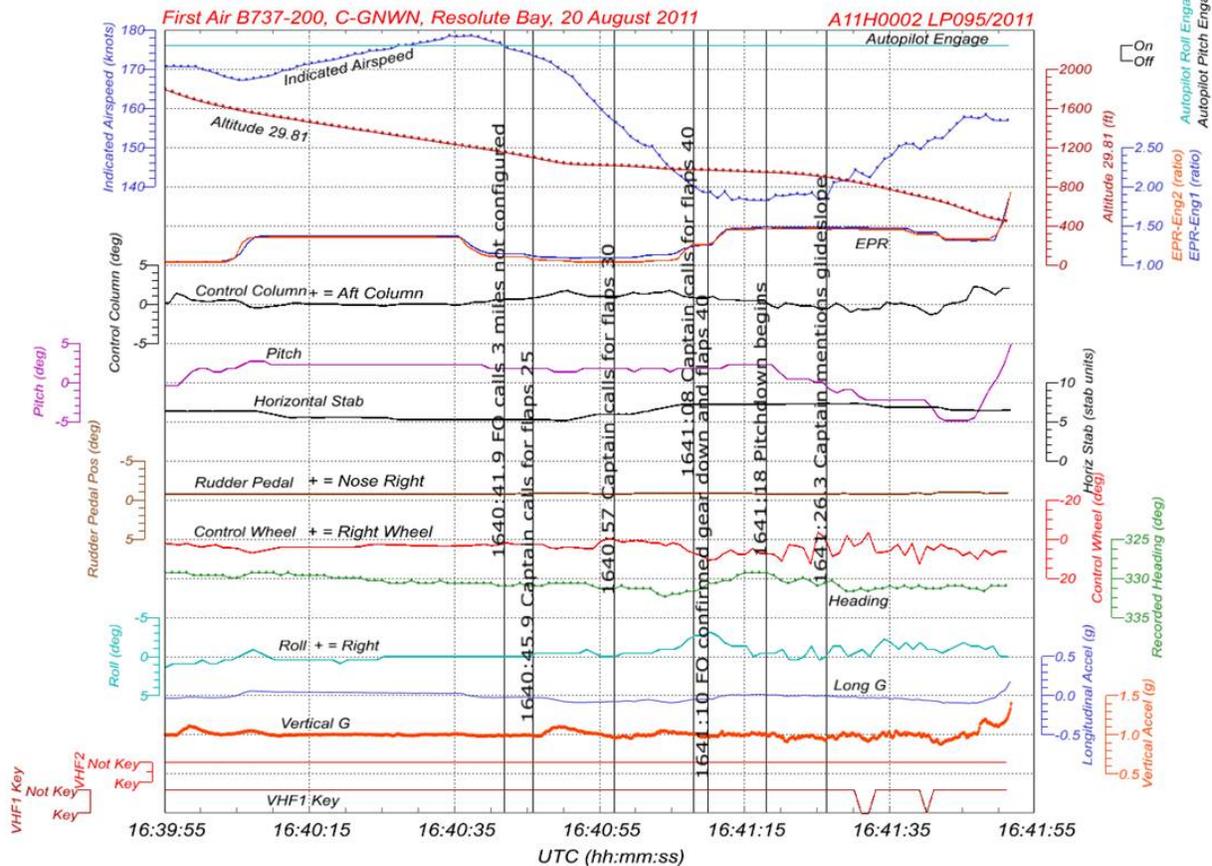
+	FAB6560 descends through 1220' ASL with 178 KIAS, 1.3 EPR and decreasing, gear down, and flaps 15.	20/08/2011 16:40:36
	First officer points out they're three miles and not configed.	20/08/2011 16:40:41
+	Captain continues approach despite go-around requirement for unstable approach.	20/08/2011 16:40:41
+	Captain calls for flaps twenty-five.	20/08/2011 16:40:45
	First officer reports full deflection on the GPS too.	20/08/2011 16:40:49
+	First officer recommends corrective action - go left.	20/08/2011 16:40:52
+	Captain indicates he can't go left.	20/08/2011 16:40:54
+	Borek909 enters control zone under IFR with no ATC separation plan from FAB6560.	20/08/2011 16:40:55
	First officer cautionary statement (re track) cut off by captain's flaps 30 call.	20/08/2011 16:40:56
+	Captain calls flaps thirty while FO raises concern regarding navigation..	20/08/2011 16:40:57

Figure 4: Sequence of Events, Safety Analysis Module

1640:23	FO states GPS is also showing to the right.
1640:25	FO questions captain as to whether they did something wrong.
1640:30	FO states opinion that they should abandon the approach and then solve the navigational problem.
1640:33	Captain indicates that he plans to continue the approach.
1640:35	FO acknowledges captain's plan to continue the approach.
1640:36	FAB6560 descends through 1000 feet above field elevation. Stabilized approach criteria become applicable.
1640:41	FO states, "We're 3 mile final; we're not configed."
1640:45	Captain calls for flaps 25.
1640:49	FO reports full deflection on the GPS too.
1640:52	FO recommends corrective action – go left.
1640:54	Captain indicates that he can't go left.

Figure 5: Sequence of Events, Word Processor Table

16:39:55 to Impact



Revised: March 25, 2013

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Figure 6: Sequence of Events - FDR Plot

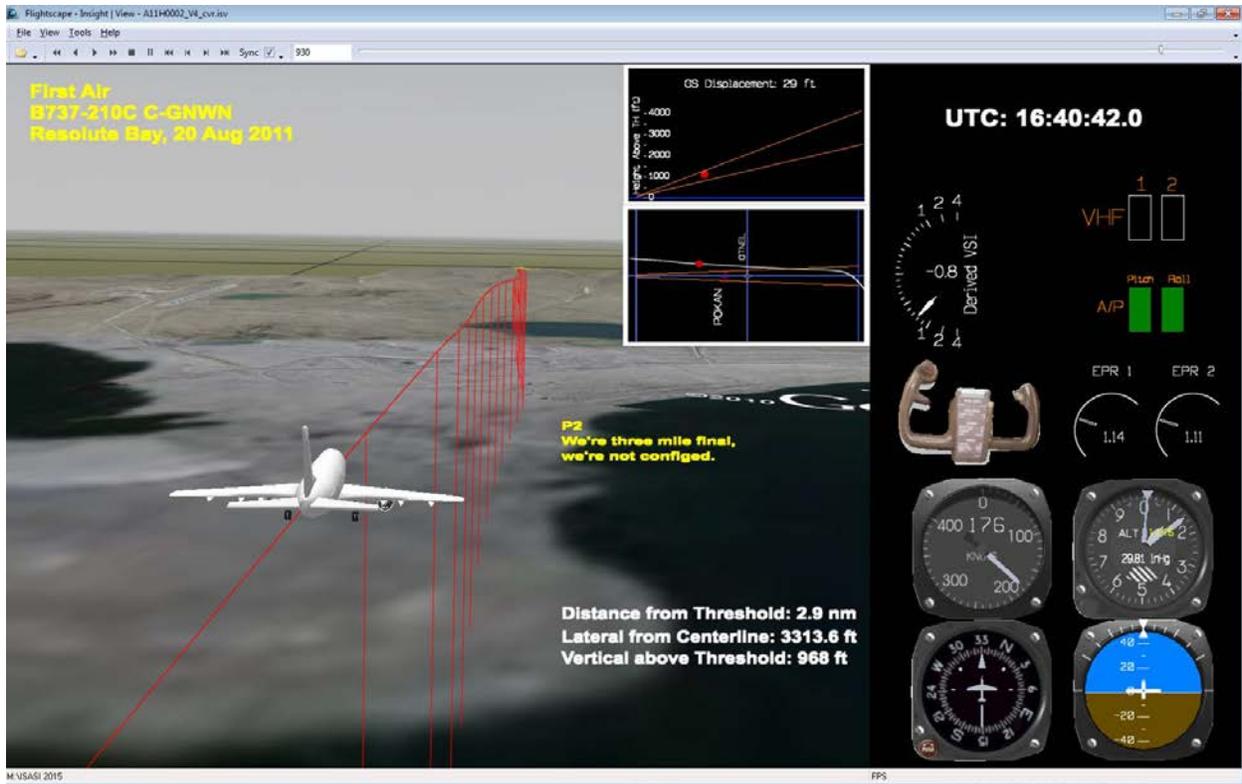


Figure 7: Engineering Flight Animation



Figure 8: Autopilot/Flight Director Mode Control Panel



Figure 9: Simulator Interior View

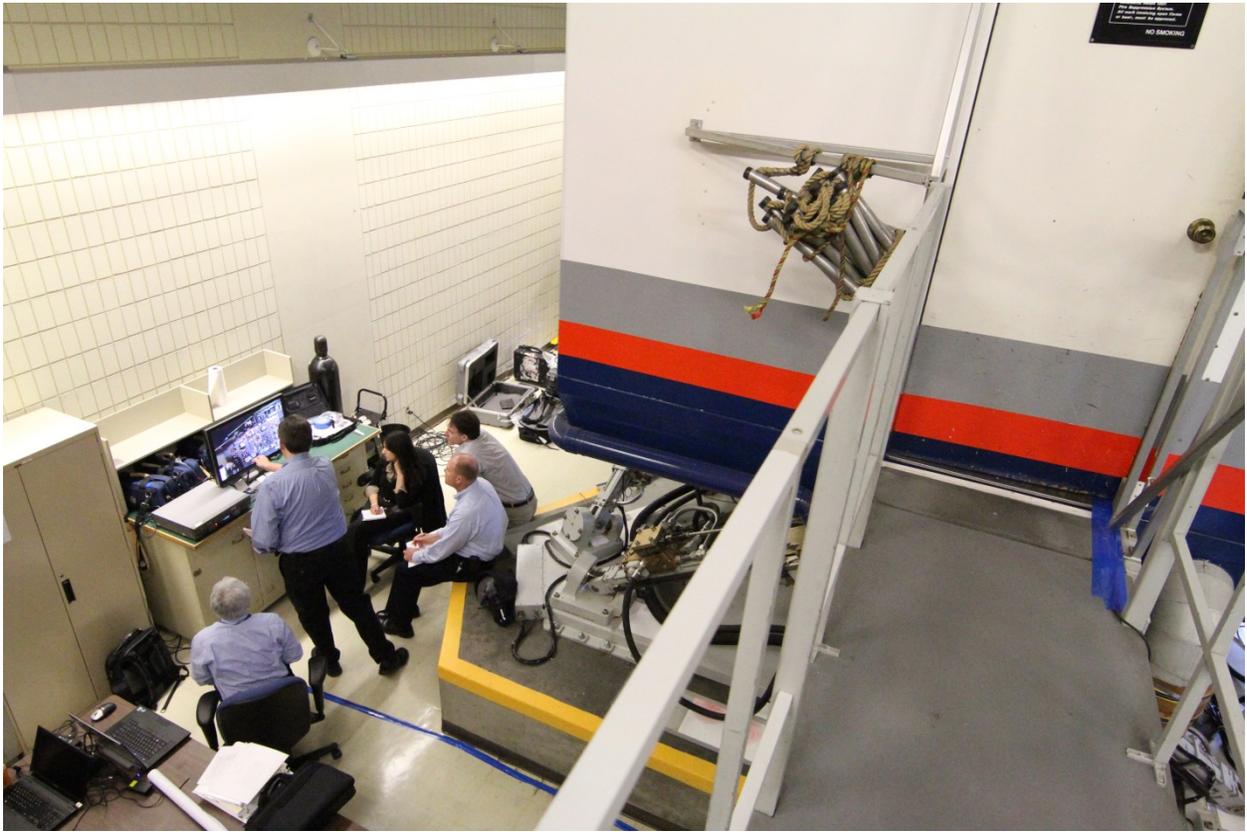


Figure 10: Simulator Exterior View

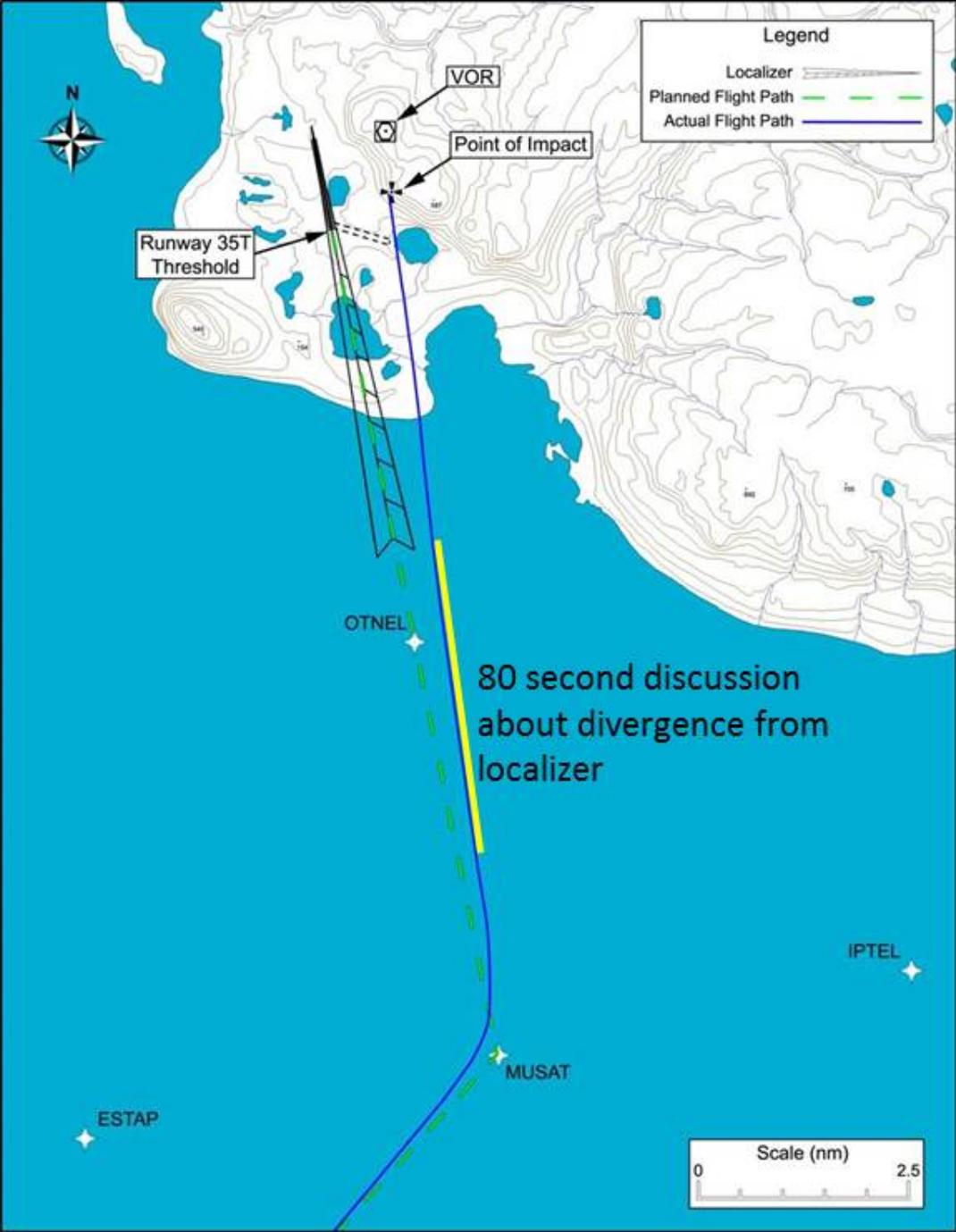


Figure 11: 80-second discussion about divergence from localizer

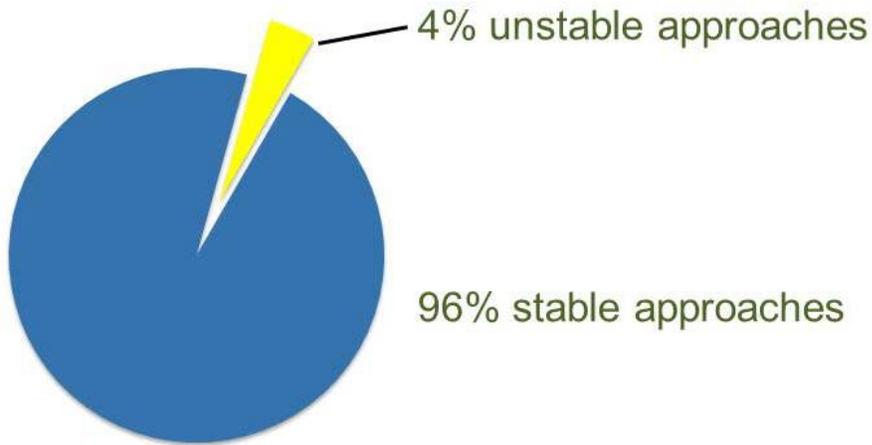


Figure 12: Unstable Approaches

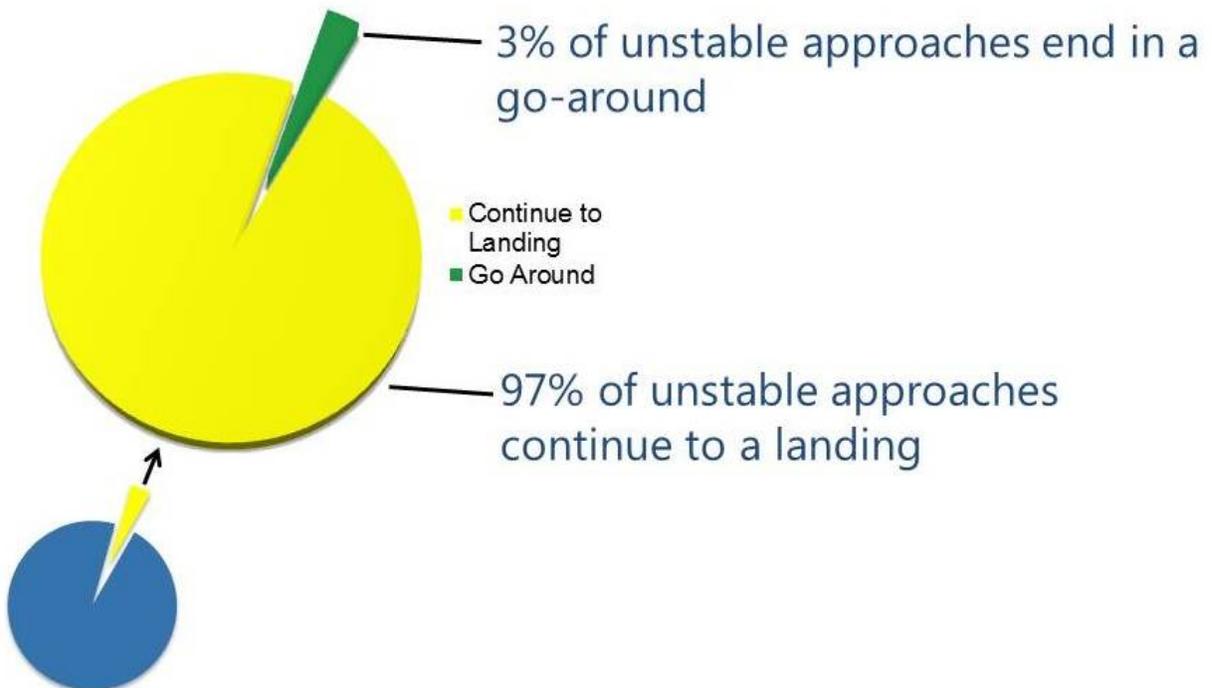


Figure 13: Unstable Approaches Continued to a Landing

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- (1) Transportation Safety Board of Canada, [Aviation Investigation Report A11H0002](#)
 - (2) LOSA Collaborative, IASS 2013, *LOSA and TEM: Some Insights Gained from 100 LOSA Projects*
 - (3) [Statistical Summary of Commercial Jet Airplane Accidents 1959-2013](#), Boeing